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by

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Effects of Plasmaspheric Ion Heating Due to Ionospheric and Magnetospheric Sources

This past year has been a period in which several studies have been brought to at least an intermediate conclusion. Two Ph. D. dissertations, which were partially supported under this grant, were concluded and conferred, although the publication of the results is only partially completed.

P. D. Craven recently concluded an extensive statistical study of N^+ behavior in the inner magnetosphere using Retarding Ion Mass Spectrometer (RIMS) data from the Dynamics Explorer 1 (DE1) satellite for high altitudes and Atmosphere Explorer RPA data for the F-region and topside ionosphere, and comparing with theoretical simulations made by the Field Line Interhemispheric Plasma (FLIP) code of Richards and Torr. Results suggest that the dynamics of N^+ are similar in most essential respects to the dynamics of O^+. However, the RIMS data indicate that the ratio of N^+ to O^+ densities decreases for increasing solar activity. Using FLIP it was found that this appears to be related to a greater increase in O^+ density than in N^+ density which occurs at the F2 peak with increasing solar activity. Whether this has a dynamic origin or is rooted in temperature dependencies of source and loss processes is still to be determined. In general, the model shows that the N^+ to O^+ density ratio tends to increase with altitude above about 1000 km for all geophysical conditions, typically ranging from 0.1 to about 1.0, and decreases with increasing ion temperature. This increase with altitude is supported by RIMS observations. The ratio varies considerably below 1000 km altitude, depending on the solar activity, the geomagnetic activity, the local time, season, and other variables.

As in previous studies, composition was found to be very sensitive to ion temperature, particularly for these heavy ions. Once observed and computed temperatures were brought into agreement, the heavy ion concentrations also matched quite well. Obtaining the temperature match generally required some amount additional heating which was obtained by invoking photoelectron trapping. This was adequate for low invariant latitudes, but not always for high latitudes, where an additional magnetospheric heat source was sometimes needed.

Another significant result of this study is that there appears to be much more N^+ in the magnetosphere, particularly above the topside ionosphere, than has generally been appreciated. Previous observations with insufficient mass resolution to distinguish N^+ from O^+ have typically attributed what was observed in this mass range to O^+. This difference could be significant for high precision resonant type processes (e.g. radiative emissions) or in quantitative comparisons of observations with detailed physical models which include realistic ion chemistry. In particular, it could have important implications for any plans involving the use of O^+ emissions for imaging the magnetospheric features in future missions. This study was documented in a Ph. D. dissertation [*Craven,* 1993]; and the topside ionosphere results have been submitted to JGR [*Craven et al.*, 1994a]. High altitude results are being prepared for submission [*Craven et al.*, 1994b].

In a second concluded Ph. D. study, Xinbo Zhang examined the effects of heavy ions on the propagation of ULF waves. The original motivation was to explore the possibility that ULF wave energy, which had propagated from the dayside magnetopause, might be dissipated at the plasmapause density gradient, resulting in the observed higher temperatures there. Reality has turned out to be much more interesting and complicated. For Pc 3 compressional waves, a cutoff between the O^+ and He^+ gyrofrequencies typically reflects the waves for typical O^+ concentrations in the outer magnetosphere. However, if the O^+ concentration becomes sufficiently high, the location of this cutoff is pushed beyond the magnetopause, thus opening the inner magnetosphere to the propagation of these waves. To the extent that heavy ion concentrations vary with solar and magnetic activity, these manifestations of geophysical activity could significantly affect the penetration of plasma wave energy into the inner magnetosphere. Similar considerations apply to Alfven mode waves, which propagate along the geomagnetic field; but the effects are restricted to high latitudes. For higher frequency waves in the Pc 1,2 range, analogous propagation effects occur, but the primary barrier for compressional mode waves is the cutoff between H^+ and He^+. And should this barrier be pushed beyond the magnetopause, the He^+-O^+ barrier serves as a backup at lower altitudes. For these waves, the energy considerations are not so important since the lower frequencies carry most of the wave power. Overall results of this study were presented in a Ph. D. dissertation [*Zhang*, 1993], and results pertaining to Pc 3 compressional mode waves were published in JGR [*Zhang et al.*, 1993]. A paper on the Pc 3 Alfven mode results is almost ready for submission to JGR [*Zhang et al.*, 1994].

We have concluded a study of an interesting phenomenon in the topside ionosphere which relates to the thermal coupling of the ionosphere to the plasmasphere. A study of the Millstone Hill incoherent scatter data taken during the 1960s and 1970s often revealed anomalous electron temperature enhancements at night in the topside. We have performed a detailed statistical study of the occurrence characteristics of these events and found that it is mostly a winter phenomenon, occurring on 70% of the January nights, but rarely in summer. However, it also occurs, with lower frequency, in all other months from September through May. The events typically occur prior to midnight and last for 2-3 hours. There is little or no correlation with magnetic and solar activity.

In the past, these temperature enhancements were attributed to density decreases in the presence of a constant heat flux from conjugate photoelectrons. However, the occurrence of these events at equinox, when conjugate photoelectron heating is non-existent, points to a more complex mechanism. Also, heating events do occur when the electron density is increasing rather than decreasing. And in those cases where the density decreases as the temperature rises, the subsequent temperature decrease usually occurs as the density continues to decrease. On the other hand, if the apparent ionospheric heating is a purely plasmaspheric phenomenon, totally independent of the conjugate photoelectron flux, it is difficult to understand why it does not occur in summer, when the ambient ionospheric temperatures are low and any heat source would be more noticeable. This study was carried out by a physics undergraduate, Trevor Garner, who has graduated and gone to graduate school at the University of Michigan. Results of this study have been published in the Journal of Geophysical Research [*Garner et al.*, 1994].

In a brief study employing temperatures at high and low altitudes, observations from DE1/RIMS and DE2/LANG were used as boundary conditions to integrate a simplified heat conduction equation with a Spitzer conductivity in order to obtain a temperature profile along a flux tube. This was done for a limited number of cases in which DE1 crossed the same flux tube a second time at low altitude (although above the DE2 crossing). This second observation was then compared with the computed profile. In general agreement was good. The cases where discrepancies were largest tended to be in the outer L-shells in the vicinity of the plasmapause density gradient. Using the calculated temperature profiles, heat fluxes to the ionosphere could also be estimated. These were found to be in the range 10^{-8} to 10^{-7} $Jm^{-2}s^{-1}$in the inner plasmasphere and up to 10^{-5} $Jm^{-2}s^{-1}$in the outer plasmasphere. Results have been reported by *Neergaard et al.* [1994]. This study has reinforced the importance of the ionosphere in its thermal coupling to the plasmasphere.

During this period we prepared and presented an invited review paper [*Comfort*, 1994a] on the thermal structure of the plasmasphere to the 1994 COSPAR symposium on Processes Active at the Ionosphere-Magnetosphere Interface. An invited manuscript [*Comfort*, 1994b] on this topic was also submitted for publication in *Advances in Space Research*. In addition, we have collaborated in a related study of ion heating in the outer plasmasphere due to Coulomb collisions with energetic ions [*Jordanova et al.*, 1993].

References

Comfort, R. H., Thermal structure of the plasmasphere, invited paper, presented to Symposium C1.3 Processes Active at the Ionosphere-Magnetosphere Interface, 30th COSPAR Scientific Assembly, Hamburg, Germany, 11-21 July, 1994.

Comfort, R. H., Thermal structure of the plasmasphere, submitted to *Adv. Space Res.*, 1994.

Craven, P. D., R. H. Comfort, and P. G. Richards, Thermal N^+ in the inner magnetosphere, to be submitted to *J. Geophys. Res.*, 1994b.

Craven, P. D., R. H. Comfort, P. G. Richards, and J. Grebowsky, Comparisons of modeled N^+, O^+, H^+, and He^+ in the mid-latitude ionosphere with mean densities and temperatures from Atmospheric Explorer, submitted to *J. Geophys. Res.*, 1994a.

Craven, P. D., Thermal N^+ in the inner magnetosphere, Ph. D. Dissertation, University of Alabama in Huntsville, December, 1993.

Garner, T. W., P. G. Richards, and R. H. Comfort, Anomalous nighttime electron temperature events over Millstone Hill, *J. Geophys. Res.*, *99*, 11411, 1994.

Jordanova, V. K., J. U. Kozyra, G. V. Khazanov, D. C. Hamilton, R. H. Comfort, D. M. Klumpar, and W. K. Peterson, Heating of thermal ions as a result of Coulomb collisions with energetic ions in the outer plasmasphere, EOS, 74, 504, 1993; presented to the Fall Meeting of the American Geophysical Union, San Francisco, CA, December 6-10, 1993.

Neergaard, L. F. J. L. Horwitz, R. H. Comfort, and P. C. Anderson, Dual spacecraft estimates of semi-analytic plasmasphere-ionosphere temperature profiles and heat fluxes, submitted to *Ann. Geophys.*, 1994.

Zhang, X., R. H. Comfort, Z. E. Musielak, T. E. Moore, D. L. Gallagher, and J. L. Green, Propagation characteristics of Pc 3 compressional waves generated at the dayside magnetopause, *J. Geophys. Res.*, *98*, 15403, 1993a.

Zhang, X., Ray tracing study of magnetospheric ULF wave propagation, Ph.D. Dissertation, *The University of Alabama in Huntsville*, December, 1993b.

Zhang, X., R. H. Comfort, Z. E. Musielak, T. E. Moore, D. L. Gallagher, and J. L. Green, Magnetospheric filter effect for Pc 3 Alfven mode waves, to be submitted to *J. Geophys. Res.*, 1994.